A Partnership for Modeling the Marine Environment of Puget Sound, Washington

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Award Number: N00014-02-1-0502
http://www.psmem.org/

LONG-TERM GOALS

Puget Sound, Washington, is both the largest fjord in the lower forty-eight states and closest to the substantial urban centers of Seattle, Tacoma, Everett and surrounding communities. The sound has seasonally high annual phytoplankton standing stock and primary production, and they support several economically valuable fisheries. Our long-term goals are to develop quantitative understanding of the Sound's circulation and marine ecosystem, and of the sensitivity of the physical and the biological system to natural and human perturbations; and to develop models of Puget Sound that can aid agencies with responsibilities for environmental management in making informed decisions and serve as marine science education tools.

OBJECTIVES

Our partnership will develop, maintain and operate a suite of flexibly linked simulation models of Puget Sound's circulation and ecosystem, a data management system for archiving and exchanging oceanographic data and model results that are accessible to all members of the partnership as well as to the regional and oceanographic community, and an effective delivery interface for the model results and observational data for research, education and policy formulation. Our partnership will conduct scientific research aimed at developing fundamental understanding of the Sound's working, as well as addressing practical questions raised by the regional community concerning management of the Sound and its resources. Our partnership will function as an estuarine research node within the NOPP Ocean Information Commons.

APPROACH

The partnership consists of five separate organizations: University of Washington (UW, School of Oceanography and College of Education), Department of Natural Resources and Parks, King County, Washington (KC-DNR), Washington State Department of Ecology (WA-DOE), Puget Sound Naval Shipyard (PSNS)/SPAWAR, and Ocean Inquiry Project (OIP). It is administered from School of Oceanography, UW. Collectively we are operating or developing four dynamically based, predictive models of the Sound's aquatic environment, each with a different spatial coverage (and a fifth module

for biogeochemistry), and our goal is to integrate these modeling efforts into a coordinated whole. Our tasks are divided as follows:

- Project coordination: Mitsuhiro Kawase (UW)
- Model operation and development:
    - Puget Sound Circulation Model: Kawase, Bruce Nairn (KC-DNR)
    - Sinclair-Dyes Inlet Model: Robert Johnston (SPAWAR), P.F. Wang (SPAWAR)
    - South Puget Sound Model: Jan Newton (WA-DOE), Skip Albertson (WA-DOE)
    - Duwamish Estuary/Elliott Bay Model: Randy Shuman (KC-DNR)
    - Aquatic Biogeochemistry Model (ABC): Allan Devol (UW), Nairn, Newton, Albertson
- Data management and infrastructure: Miles Logsdon (UW), Mark Warner (UW)
- Education and visualization: William Winn (UW), Fritz Stahr (OIP)

Washington State Department of Ecology personnel include Jan Newton and Skip Albertson. They are primarily involved in model operation and development, but contribute to the data management task, as well, to assure continuity and accessibility across partner databases.

WORK COMPLETED

In addition to participating in the PSMEM workshop and the development of the Aquatic BiogeoChemistry Model (ABC), as described in the annual report submitted by Kawase, Ecology's contributions to the partnership were:

- Collection of 2004 hydrographic and ADCP data in South Puget Sound via a week-long cruise on the R/V Barnes (27 September -1 October); the cruise covered approximately 80 stations and collected end-of-summer results at the conclusion of a drought (Fig. 1)

- Completion of the closest-approach model comparison between EFDC (used by Ecology) and ABC (being developed by partnership); these results will be available shortly as a brief report.

- Presentation of PSMEM partnership results at the Restore America's Estuaries meeting held at the Seattle Conference Center 12-15 September 2004 (Albertson, Newton Sept 2004).

- Organization of the JEMS boundary condition data for the year 2000 ABC run for the entire Puget Sound (just beginning).

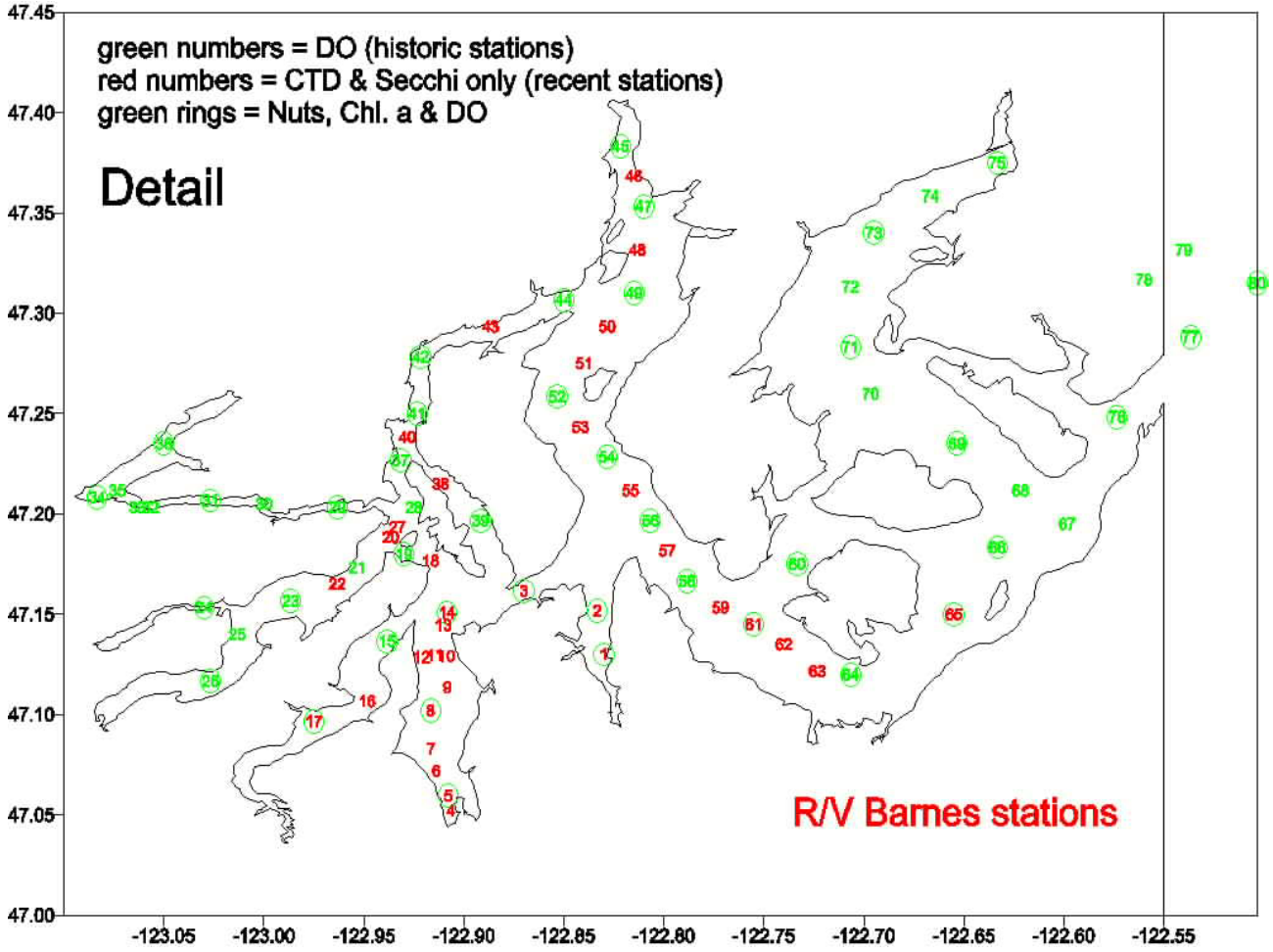

Figure 1. The 80 stations from South Puget Sound from which hydrographic data were collected during September 2004.

RESULTS

Ecology's South Puget Sound model has been applied to several recent problems in more urban embayments in the region. In keeping with the flexible hierarchy of these models, we simulated the dilution of effluent from a Waste Water Treatment Plant near the City of Shelton (Fig. 2) at higher resolution than our original model. We have also modeled oxygen levels at depth in Budd Inlet near Olympia for longer time periods than before to look at the effects of interannual variablity (Fig. 3). Both of these determinations were driven by listings under section 303-d of the Clean Water Act.

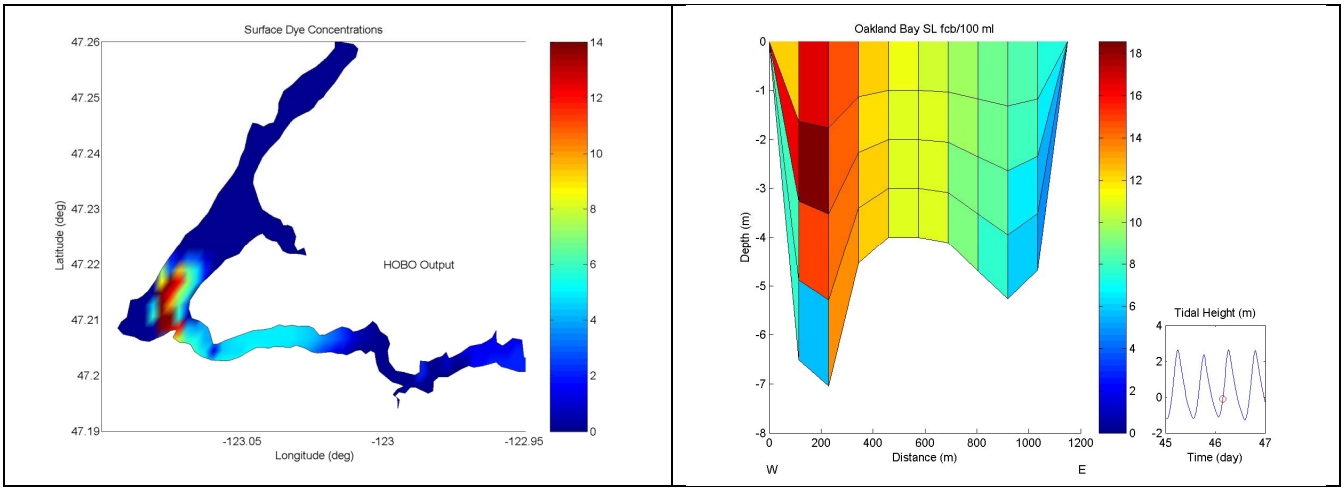

Figure 2. Plan and section views of a dye release simulation in Oakland Bay made with HOBO with 50 to 200-m resolution.

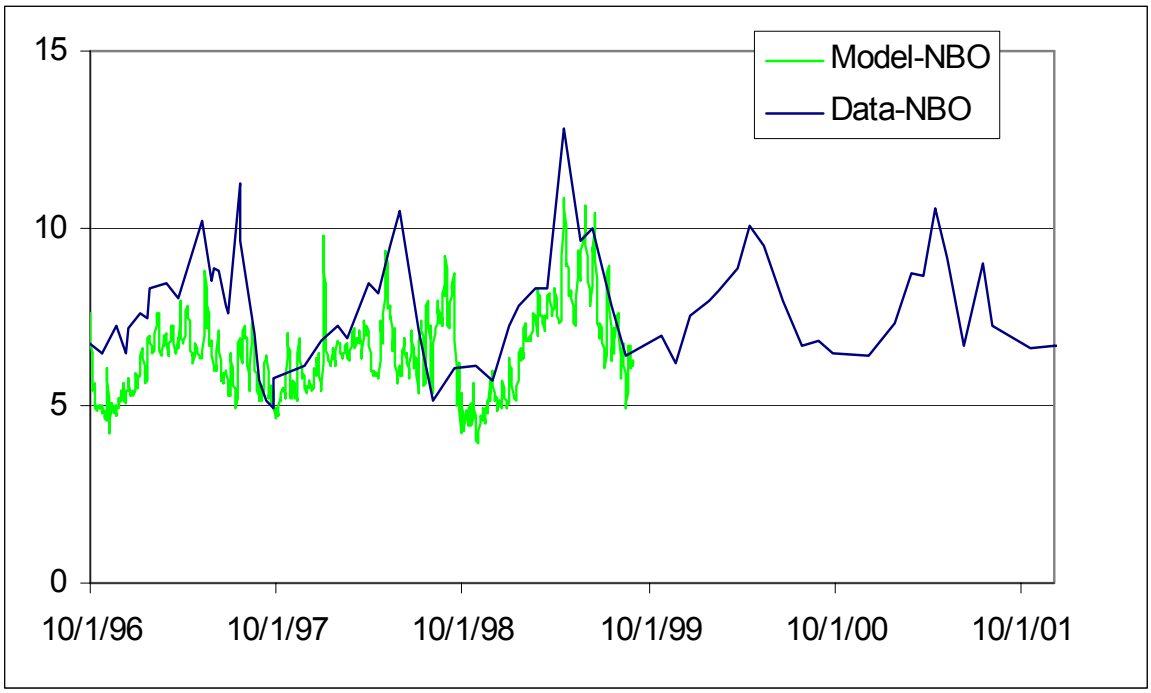

Figure 3. A multiyear simulation for near-bottom oxygen from Ecology's South Puget Sound model in Budd Inlet's inner West Bay, near Olympia with normal 500 to 600-m resolution.

IMPACT/APPLICATIONS

Economic Development

Predictive modeling of Puget Sound's circulation and marine ecosystem will have positive impacts on many economic activities taking place in the Sound. We made an application this year at the extreme SW terminus of Puget Sound. The city of Shelton is growing and considering the possibility of increasing their wastewater discharge via an outfall that straddles two (sanitary) lines, which define a shellfish closure zone in Oakland Bay and Hammersley Inlet. Ecology developed a high-resolution model (order 50-100m) to help the Washington State Department of Health (WDOH) evaluate conditions along these sanitary lines. We developed a specific version of the Environmental Fluid Dynamics Code (EFDC) for the Hammersley Oakland Bay Oceanographic (HOBO) model. HOBO is driven by real data acquired at its boundaries. We calibrated the model for tidal response, and then confirmed the model by testing its response at three locations to a dye release. Finally, we used the HOBO model to simulate various discharge scenarios and to determine consequences at the two sanitary lines during periods specified by WDOH. Model results show that extending the diffuser horizontally across Hammersley Inlet can be very effective in controlling the far-field dilution at the sanitary line, although releasing effluent further north toward Munson and away from Eagle Point can cause problems on the east end of the Oakland Bay sanitary line. Holding back effluent at slack tide is another very effective method for controlling initial dilution at the sanitary lines. Controlling the vertical plume trapping depth is not very effective as a control method since there is a substantial amount of vertical mixing in this estuary, and the plume is mixed regardless by the time it gets to either sanitary line. We also determined an overall flushing time for Oakland Bay of about five days, which differs substantially from tidal prism estimates where the volume of one flood tide more than replaces the volume of Oakland Bay in one tidal cycle. This is due to tidal refluxing of greater than 90% the same water ejected on the ebb tide.

Quality of Life

The HOBO model has implications for an upcoming TMDL in Oakland Bay on fecal coliform bacteria. The TMDL will take into account bacteria die-off rates as well as the dilution effects addressed by the HOBO simulations.

Science Education and Communication

In addition to www.psmem.org, aspects of public interest specific to Ecology's modeling are mainly communicated via websites we maintain at
http://www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html and
http://www.ecy.wa.gov/programs/eap/spasm/index.html

TRANSITIONS

Quality of Life

Ecology will be testing the sensitivity of Sound Puget Sound to eutrophication during 2005 by running the model with increased nutrient source loading. The results of this study will have important consequences to water quality issues in both of Ecology's western regional offices.

RELATED PROJECTS

Ecology, through the partnership, continues a strong cooperative relationship with Puget Sound Regional Synthesis Model (PRISM, www.prism.washington.edu), a University of Washington project to develop and consolidate University-wide expertise in natural and human environment of the Puget Sound region.

REFERENCES

Albertson, S. and J. Newton. Towards A Greater Understanding of Puget Sound through Modeling Restore America's Estuaries Second National Conference, September 2004.

Albertson, S. Oakland Bay Study – a dye and modeling study in an enclosed estuary with a high degree of refluxing. Washington Dept. of Ecology Publication No. 04-03-020. May 2004.